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Pan Technical Systems, Inc.

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3722 PARK PLACE
MONTROSE, CALIFORNIA

3 December 1965

TITLE

FINAL REPORT
CERAMIC CAPACITOR ACCELERATED
LIFE TEST PROGRAM
JPL TEST PROCEDURE
152.20-03
CONTRACT No. 951125

APPROVED BY: Howard W. Hesse

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, pursuant to a subcontract issued under Prime Contract NAS7-100 between the California Institute of Technology and the United States of America represented by the National Aeronautics and Space Administration.

ABSTRACT

N66 17341

This report describes the tests and the results of a matrix-type, 2,688-hour accelerated life test performed on 1,960 fixed ceramic capacitors manufactured by Aerovox. These capacitors represent "advanced-state-of-the-art" components with respect to size vs. capacitance value.

The purposes of the test were:

1. To accurately determine the suitability of this type of component for spacecraft applications.
2. To determine or verify the existence of temperature and voltage stress acceleration factors during life testing.
3. To accumulate and record failure data and attributes data regarding the parametric behavior of the parts throughout the test series.

The IDEP Summary Sheets immediately following this abstract provide an account of the results of this test insofar as parts tested, tests performed and results obtained based on catastrophic failures alone. No a priori drift tolerances were established for this program; therefore, no parametric type failures are considered.

A total of 37 failures was noted during the entire program. Ten of these were rejects which occurred during initial visual inspection and measurements. Two additional failures resulted during a 250-hour pre-life test screening burn-in.

The remaining 25 failures took place during the 2,688-hour life test. Three of these were mechanical (broken leads). The other 22 are shown in the following tabulation by stress matrix cells:

author

Temperature	Voltage	No. of Failures
$25^{o}C$	400	1
$70^{o}C$	50	1
$125^{o}C$	400	4
$145^{o}C$	200	4
$145^{o}C$	400	12
	Total	22

The above tabulation indicates that 20 out of 22 electrical failures (91%) occurred in the three highest stress cells. The remaining failures were distributed randomly. Of the entire 20-cell matrix, 12 cells had no failures and three additional cells contained only mechanical failures.

IDEP FORM NO. 17:10-62

GENERAL REPORT SUMMARY SHEET

1. COMPONENT/PART NAME PER GENERIC CODE Capacitor, Fixed Ceramic, Lead Mount	2. PROGRAM OR WEAPON SYSTEM
	3. TEST COMPL. DAY 17 MO. 11 YR. 65; REPT. COMPL. DAY 3 MO. 12 YR. 6[illegible]
4. ORIGINATOR'S REPORT TITLE Ceramic Capacitor Accelerated Life Test	5. ORIGINATOR'S REPORT NO. 152. 20-03
	6. TEST TYPE, ETC. Evaluation to JPL Requirements

7. THIS TEST (SUPERSEDES) (SUPPLEMENTS) REPORT NO:

8. OUTLINE, TABLE OF CONTENTS, SUMMARY, OR EQUIVALENT DESCRIPTION:

This report gives the results of an accelerated matrix life test performed on 1960 fixed ceramic capacitors manufactured by Aerovox.

After initial inspection and measurements, 2,184 specimens were subjected to a screening burn-in of 250 hours duration at 125°C with 50 volts DC applied.

After burn-in, 1960 capacitors were used to form a 20-cell life test matrix operated for 2,688 hours at four temperatures and five voltage levels.

Table of Contents

11. REPT. NO.

9. SIGNED

10. CONTRACTOR

SUBCONTRACTOR Pan Technical Systems, Inc.

IDEP FORM NO. 1A 9-62

REPORT SUMMARY SHEET

1. COMPONENT/PART NAME PER GENERIC CODE	2. PROGRAM OR WEAPON SYSTEM	3.	DAY	MO.	YR.
Capacitor, Fixed Ceramic, Lead Mount	5. ORIGINATOR'S REPORT NO. 152. 20-03	TEST COMPL.	17	11	65
4. ORIGINATOR'S REPORT TITLE: Ceramic Capacitor Accelerated Life Test	6. TEST TYPE, ETC.: Evaluation to JPL Requirements	REPT. COMPL.	3	12	65

7. THIS TEST (SUPERSEDES) (SUPPLEMENTS) REPORT NO:

ITEM	8A. PART TYPE, SIZE, RATING, LOT, ETC.	9. VENDOR	10. VENDOR PART NO.	11. IND./GOV. STD. NO.	12 TOTAL TESTED
1	Capacitor 0.1 mfd +20% 50V Radial Lead Flat Ceramic	Aerovox	JMC 605C104M		2194
2					
3					
4					(OVER)

13. INTERNAL SPECS. ETC REQ'D TO UTILIZE REPT.	ENCL	SENT WITH REPORT NO.	14. MIL. SPECS./STDS. REFERENCED IN 15C
A JPL Test Procedure			D
B No. 152. 20-03			E
C			F

15A. ITEM	TEST OR ENVIRONMENT	C PER SPEC	D SPEC. PARAGRAPH/ METHOD/CONDITION	E TEST LEVELS, DURATION AND OTHER DETAILS	F NO. TESTED	G NO. FAILED	
All	Viaual Inspection	X	JPL 152. 20-03	Examine for Defects 5X Magnification	2194	3	(1)
All	Inital Measurements	X	"	Capacitance, Dissipation Factor, Insulation Resistance	2191	7	
All	Screen Burn-In	X	"	250 hours; 125^{O}C, 50V	2184	2	
01	Life	X	"	2688 hours; 25^{O}C, 0V	90	0	
02	Life	X	"	2688 hours; 25^{O}C, 50V	100	0	
03	Life	X	"	2688 hours; 25^{O}C 100V	100	0	
04	life	X	"	2688 hours; 25^{O}C, 200V	100	0	
05	Life	X	"	2688 hours; 25^{O}C, 400V	100	1	
06	Life	X	"	2688 hours; 70^{O}C 0V	90	0	

(OVER)

21. REPT. NO.

16. SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN:

(1) Failure definition is open, short or mechanically unfit to function.

(OVER)

17. TESTED BEYOND VENDOR CATALOG SPECIFICATIONS	18. VENDOR INFORMED OF TEST RESULT BY:	19. SIGNED	20. CONTRACTOR	SUBCONTRACTOR
YES [X]	LETTER [ ] CY OF REPT [X] ORAL [ ]			Pan Technica Systems, Inc.

ICEP FORM NO. 18 9-62

ITEM	8A. PART TYPE, SIZE, RATING, LOT, ETC.	9. VENDOR	10. VENDOR PART NO.	11. IND./GOV. STD. NO.	12 TOTAL TESTED
5	Capacitor 0.1 mfd $\pm$20%, 50V Radial Lead Flat Ceramic	Aerovox	JMC 605C104M		2194
6					
7					
8					

15A. ITEM	TEST OR ENVIRONMENT	C PER SPEC	D SPEC. PARAGRAPH/ METHOD/CONDITION	E TEST LEVELS, DURATION AND OTHER DETAILS	F NO. TESTED	G NO. FAILED
07	Life	X	IPL 152.20-03	2688 hours; 70^{O}C, 50V	100	1
08	Life	X	"	2688 hours; 70^{O}C, 100V	100	0
09	Life	X	"	2688 hours; 70^{O}C, 200V	100	0
10	Life	X	"	2688 hours; 70^{O}C, 400V	100	0
11	Life	X	"	2688 hours; 125^{O}C, 0V	90	0
12	Life	X	"	2688 hours; 125^{O}C, 50V	100	0
13	Life	X	"	2688 hours; 125^{O}C100V	100	1
14	Life	X	"	2688 hours; 125^{O}C 200V	100	1
15	Life	X	"	2688 hours; 125^{O}C, 400V	100	4
16	Life	X	"	2688 hours; 145^{O}C 0V	90	0
17	Life	X	"	2688 hours; 145^{O}C, 50V	100	1
18	Life	X	"	2688 hours; 145^{O}C, 100V	100	0
19	Life	X	"	2688 hours; 145^{O}C, 200V	100	4
20	Life	X	"	2688 hours; 145^{O}C, 400V	100	12

16. SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN:

21. REPT. NO.

CONTENTS

I. INTRODUCTION

Contract No. 951125 was awarded to Pan Technical Systems on 27 January 1965 for the purpose of conducting a four-temperature, five-voltage, matrix, 2,688-hour life test on 1,960 miniature, fixed, 0.1 mfd. ceramic capacitors manufactured by Aerovox, Part No. JMC605C104M.

Cells in the matrix ranged in combinations from zero to 400 volts DC and from 25°C to 145°C in temperature in order to provide data to determine temperature and voltage stress acceleration factors. In addition, of course, the life test constituted a valid measure of the acceptability of these capacitors for use in spacecraft applications.

Failure data was logged during the entire period and is covered in Part VII of this report. Detailed statistical analyses of variables are not included since this was not within the scope of the contract; however, all measurements, recorded on punched cards, have been forwarded to JPL.

Test specimens were furnished by JPL and were received by PTS on 1 February 1965. Initial operations were begun the following day. Final measurements were completed on 17 November 1965. No interruptions or delays were encountered during the course of performance except for the following:

1. Initial readings of Leakage Current indicated, in some cases, negative amounts. Further operations were suspended thereafter during several conferences with cognizant JPL personnel. This subject is covered in Section IV of this report, page 4-3.
2. Prior to beginning the life test, a contract modification was issued which altered the original test design by eliminating 16 of the matrix cells. Life testing was delayed pending the issuance of this modification.

All tests were performed at Pan Technical Systems, Inc. 3722 Park Place, Montrose, California, in accordance with JPL Test Procedure No.

152. 20-03 dated October 5, 1964, as modified by Technical Direction Memorandums No. 1, 2, 3 and 4 dated 2/12/65, 3/11/65, 5/25/65 and 6/9/65 respectively, and Contract Modification No. 1 and 2 dated 6/3/65 and 8/25/65. (Both of the latter covered essentially the same change.)

All calibrations of test or measurement equipment referred to in this report are traceable to the National Bureau of Standards through documents on file at Pan Technical Systems, Inc., and/or the commercial calibrating agency referenced in the text.

II. DESCRIPTION OF TEST ITEM

Name:	Capacitor, Fixed Ceramic
Manufacturer:	AerovoxManufacturing Co.
Capacitance:	0.1 mfd $\pm$20%
Dissipation Factor:	Less than 2.5%
Voltage	50V (Rated)
Physical Dimensions:	.295" x .245" x .095"
Case Style:	Square, radial leads

III. TEST DESIGN

The major stress segments of the test program consisted of the following:

1. Screening burn-in (2,194 components)
2. Matrix life test (1,960 components)

Initial Inspection

An initial inspection was performed as the first step in order to verify that all samples bore the manufacturer's name, trademark or symbol and that each was correctly marked with respect to capacitance, tolerance and voltage rating. In addition, all items were examined under 5X magnification for evidence of cracked cases, defective molding, damaged or corroded leads or other signs of poor workmanship.

Serialization and Grouping

Concurrent with the visual and mechanical inspection, all test items were counted and divided into groups corresponding to the various matrix cells established for life testing, plus a group of spares.

All test samples were delivered in individual envelopes labeled "+" or "-" by the manufacturer, designating that the capacitor contained in each envelope was either over or under the nominal value of 0.1mfd., according to the marking. On-third of the total quantity was labeled "+". The remaining two-thirds were labeled "-".

In selecting the individual samples assigned to each life test group, a random process was followed except that one-third of each group was selected from the "+" category and the remaining two-thirds were selected from the "-" category in order to insure an even distribution of these classes throughout the matrix.

After the random selection of components forming the life test groups was completed, all components were serialized and tagged.

Tags were furnished by JPL and, for life test matrix, serial numbers ran from C103001 to C104960, a total of 1,960. Serial numbers in perfect sequence were not provided for the spares group, consequently these were numbered as follows:

From	To	Total
B15401	B15500	100
B16001	B16100	100
B17206	B17239	34
	Total Spares Group	234

At this point, for the sake of clarity, two items must be mentioned. First, the tag serial numbers are not the same as the JPL "Item Number" by which, in accordance with instructions and JPL Specification ZPP-2090-Gen, all individual readings were identified. A cross-reference list is provided in Appendix A which relates these two numbers series to each other.

Second, the life test matrix cells originally established were in accordance with those as planned by JPL at the outset of the contract. Before the life test was actually started, however, a contract revision reduced the number of cells from 36 to 20. The components originally assigned to the 16 cells which were eliminated were re-assigned to cells 1, 6, 11 and 16, thereby creating a discontinuity in the tag numbers for these particular cells.

At the time this change was made, before any readouts were reported to JPL, all necessary revisions were made in the JPL Item Numbers assigned to each group affected, so that all Item Numbers within the revised Groups are in sequence with no missing or duplicate numbers.

A comparison of the matrix originally planned and the revised matrix is shown in Figure 3-A.

ORIGINAL GROUP I

	$25^{o}C$	$70^{o}C$	$125^{o}C$	$145^{o}C$	
	5) 100	10) 100	15) 100	20) 100	400 VDC
	4) 100	9) 100	14) 100	19) 100	200
	3) 100	8) 100	13) 100	18) 100	100
	2) 100	7) 100	12) 100	17) 100	50
	1) 50 + 40	6) 50 + 40	11) 50 + 40	16) 50 + 40	0

TRANSFERRED BY REVISION #1

21 - 24 to 1

25 - 28 to 6

29 - 32 to 11

33 - 36 to 16

ORIGINAL GROUP II

24) 10	28) 10	32) 10	36) 10	400 VDC
23) 10	27) 10	31) 10	35) 10	200
22) 10	26) 10	30) 10	34) 10	100
21) 10	25) 10	29) 10	33) 10	50 — 37) Spares
$25^{o}C$	$70^{o}C$	$125^{o}C$	$145^{o}C$	

Figure 3-A

FLOW DIAGRAM OF TESTS

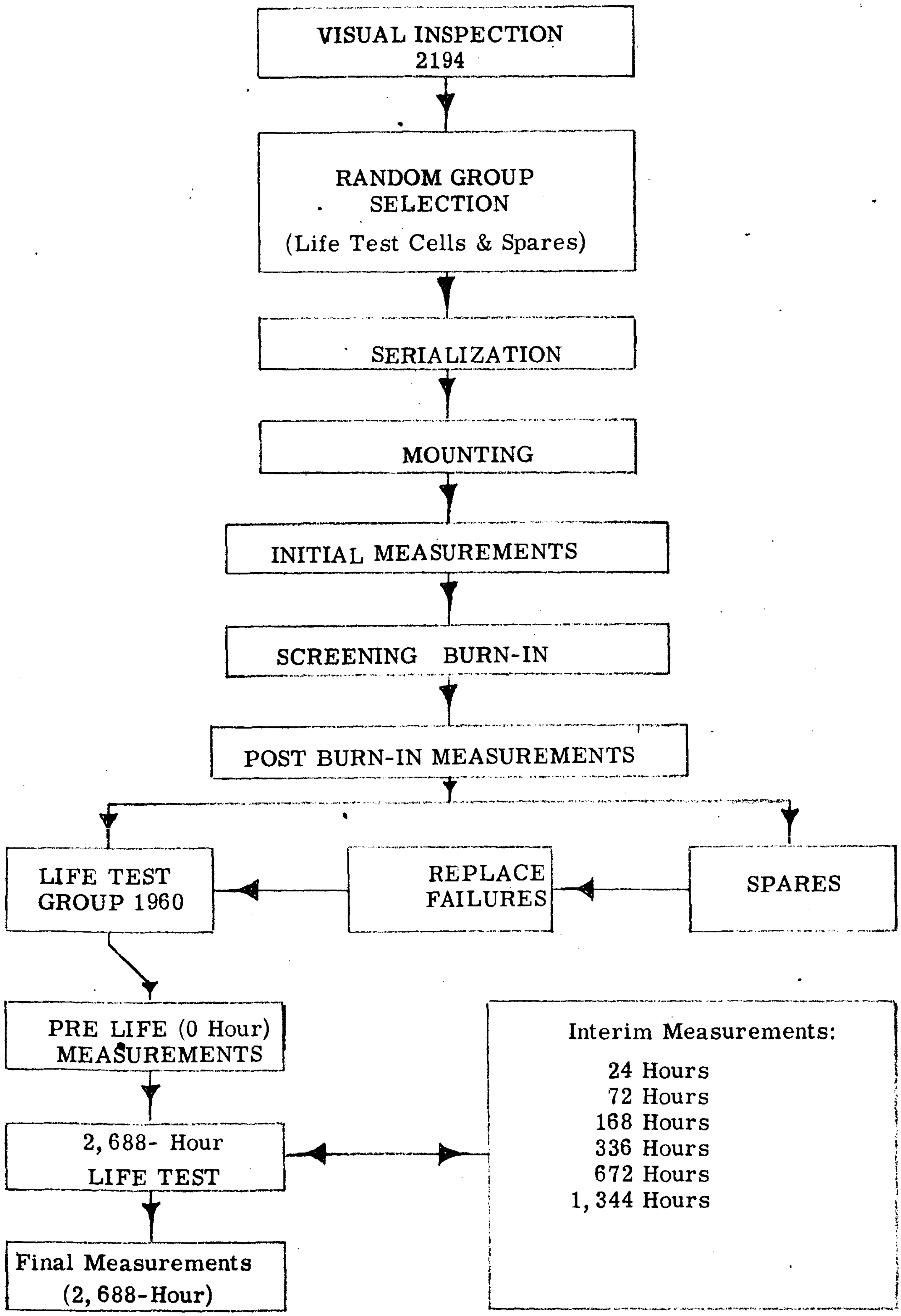

Figure 3-B

Screening Burn-In

Initial measurements (Measurement Code 01) were performed at this point, followed by a 250-hour burn-in at 125° ±5°C with 50 VDC applied. All samples, a total of 2,191 capacitors, were included with the exception of three rejected during initial inspection for broken leads.

Post burn-in measurements (Measurement Code 02) were completed immediately following the burn-in period. It was originally planned that this data would also constitute the zero-hour life test readings. It was at this time, however, that the revision of the life test matrix was taking place which resulted in a delay in beginning the life test. Therefore, a separate measurement (Measurement Code 03) was made immediately prior to the start of life testing.

Life Test

The following tabulation indicates the measurements made during the life test:

Measurement Code	Elapsed Hours
03	0
04	24 ± 1
05	72 ± 1
06	168 ± 4
07	336 ± 8
08	672 ± 8
09	1,344 ± 12
10	2,688 ± 12

Adherence to the foregoing schedule was maintained by staggering the start time of the various groups plus second-shift operations as required through completion of the 168-hour readouts. After this point was reached, subsequent readouts were spaced sufficiently far apart so that no timing problems were experienced.

Matrix Cells employed for the life test are shown below with each associated temperature and voltage:

Group No.	Specimen Quantity	Temperature	Voltage
1	90	25°C	0
2	100	25°C	50
3	100	25°C	100
4	100	25°C	200
5	100	25°C	400
6	90	70°C	0
7	100	70°C	50
8	100	70°C	100
9	100	70°C	200
10	100	70°C	400
11	90	125°C	0
12	100	125°C	50
13	100	125°C	100
14	100	125°C	200
15	100	125°C	400
16	90	145°C	0
17	100	145°C	50
18	100	145°C	100
19	100	145°C	200
20	100	145°C	400

IV. MEASUREMENT PROCEDURES

Capacitance and Dissipation Factor

Capacitance and Dissipation Factor were measured by means of a General Radio Impedance Bridge, Type 1608A, Serial #221 operated in the C_s (series capacitance) configuration. A 1000 cps 2.0 volt test signal was provided to the capacitors under test by exciting the bridge with a Hewlett Packard Type 650A Oscillator, Serial #203-10133. Constant excitation was used throughout the test program. Balancing was accomplished by use of the selective internal selector supplied as a part of the bridge.

The manufacturer's rated accuracy is:

Capacitance (on range used) $\pm 0.1\% \pm .005$ of full scale

Dissipation Factor $\pm 5\% \pm .005$

Since the bridge was operated at approximately 90% of full scale, the accuracy for capacitance measurements exceeded the requirements of $\pm 0.5\% + 0.2\ \mu\mu f$, as specified in the JPL Test Procedure No. 152.20-03, by 1/2 order of magnitude.

Tests performed at PTS on the calibration of the DF dial showed that this bridge actually met the requirement of $\pm 2\% \pm .005$ on DF as required by the JPL Test Procedure.

Calibration of this bridge is scheduled on an annual recall basis. At the time the program was begun, the latest calibration date was August 20, 1964. The calibration period therefore expired in August, 1965. Just prior to the expiration of the calibration period (July 26, 1965), comparison readings were made using combinations of a silver mica capacitor and film resistors. An analysis of the variables indicated that no significant drift had taken place since the calibration date. It was therefore recommended, since further data was still to be accumulated at that time, that the calibration period be extended to the completion of the contract in order to avoid the possibility that recalibration during the contract might slightly alter the readings, particularly in the case of Dissipation Factor.

Immediately after final measurements were made, this instrument was sent out for calibration and was found to be in good condition and still within the manufacturer's stated accuracy. The date of this latest calibration was November 28, 1965. The calibration agency was Precision Standards Laboratory.

As a matter of record, the readings made on August 24, 1964, immediately after the 1964 calibration, and on July 26, 1965, are shown below:

Capacitance		Dissipation Factor	
8-24-64	7-26-65	8-24-64	7-26-65
.03260	.03260	.0001	.0002
.03260	.03260	.0104	.0103
.03260	.03260	.0312	.0311
.03260	.03260	.0915	.0914
.03260	.03260	.282	.286
.03260	.03260	.857	.857

Leakage Current

Leakage Current was measured by means of a Hewlett Packard 425A Milli-microvolt Ammeter, Serial No. 06530. This instrument provides an accuracy of 3% of full scale (10% at range switch points) and was acquired by PTS specifically to fulfill the requirements of this program. Since this instrument was new at the beginning of the program, it remained within the manufacturer's initial calibration period throughout the duration of the contract.

The polarization period specified by Test Procedure No. 152.20-03 required the application of 100 VDC for a two minute period after which the leakage current was measured within a time tolerance of ± 5 seconds. In order to achieve the required cycling accuracy, a PTS-designed semiautomatic sequencer was built providing a constant two minute polarization cycle. This device had an insulation resistance greater than 1×10^{12} ohms at room temperature and also provided shielding for the capacitors during the time measurements were taken.

A 100 1/2 (45 + 45 + 6 + 4 1/2) volt battery was employed, initially, as the electrification source in making the leakage current measurements. At the time the initial measurements were made, a large number indicated a reverse current flow. At this point a complete review of all instrumentation was performed in conjunction with cognizant JPL personnel which included the voltage source, fixture leakage, substitution of other fixtures for comparison, possible ground loops, thermoelectric effects, substitution of meters and shielding. No definite cause for this effect was discovered and, after several conferences, it was decided to continue the tests, recording negative leakage current measurements as they occurred.

At a later point in the tests, prior to Measurement No. 03 (0-hour life test readout) the battery was replaced by a Hewlett Packard Power Supply, Model 711A, plus an extra RC filter network, to provide the polarization voltage. This seemed to slightly decrease the number of negative readings; however, the actual results were inconclusive.

Battery and power supply voltages were monitored by a Fluke Differential Voltmeter, Model 803B, Serial No. 1499, with a manufacturer's stated DC accuracy of 0.05% which in turn, was calibrated by an ESI Model 300PVB Portametric Voltmeter Bridge, Serial No. 42 4029 having a stated accuracy of 0.02% and within the manufacturer's initial calibration period beginning August 20, 1964.

Standard Condition

All measurements were made at an ambient temperature of $25^{\circ}C \pm 3^{\circ}C$, an atmospheric pressure of 28 to 32 inches of mercury and a relative humidity of not more than 70%. Moisture condensation caused by reducing the specimens to $25^{\circ}C$ prior to measurements was not observed at any time during the program and forced air drying was not necessary.

Prior to each measurement, a minimum of one hour was allowed for discharging (shorting) the capacitors under test after disconnecting the test voltage in accordance with Technical Direction Memorandum No. 1 dated February 12, 1965.

All measurements were performed with the serialization tag facing the measurement technician in order to maintain consistent polarity for each specimen.

Handling

Special care was employed in handling the test specimens in order to eliminate effects of pressure, temperature or moisture contamination.

Initial measurements of Capacitance and DF were conducted with the capacitors mounted on a non-conductive plastic screen. Contact to the leads was made by means of clips. Subsequent measurements were made with the parts mounted on their respective test fixtures with paralleling fuses removed.

When demounting the specimens for leakage current measurements, white gloves were worn in order to minimize body capacitance and conductivity effects. The same procedure was employed for remounting.

Fixture location positions were maintained constant throughout the test for each capacitor. Mounting was always in the same direction, thereby ensuring a consistent polarization direction.

All measurements were made within a 24 hour period after each environmental stress exposure.

V. ENVIRONMENTAL TEST PROCEDURES

Screening Burn-In

All test specimens were subjected to a 250-hour screening burn-in at $125^{\circ} \pm 5^{\circ}C$ with 50 $\pm$2 volts DC connected. Peak charge and discharge currents were limited to less than 10 ma.

The burn-in was performed in the Enviratron Environmental Test Chamber, Model 1243. Temperature was controlled by U.E. Type E32N Controllers capable of maintaining $\pm 5^{\circ}F$. Temperature was monitored by a Honeywell Brown Chart Recorder calibrated by Honeywell, Inc. Applicable calibration dates were December 29, 1964, April 8, 1965, June 10, 1965, August 18, 1965 and October 20, 1965.

The stress voltage of 50 VDC was provided by a Hewlett Packard Power Supply, Model 711A, monitored by a Hewlett Packard VTVM, Model 412A, Serial No. 134-05485 with a manufacturer's stated accuracy of $\pm$1% F.S. Calibration of this instrument was performed by the Librascope Metrology Laboratory January 6, 1965, and again on October 13, 1965 by PTS, using the ESI Model 300 PVB Portametric (0.02% stated accuracy, calibrated August 20, 1964 by the manufacturer).

Appropriate series resistors were employed to limit the charging current to a maximum of 10 ma.

Life Test Matrix

The setup used for performing the life test is illustrated in Figure 5A. Environmental temperatures were maintained in the 4-bay Enviratron Multiple Test Chamber apparatus and controlled within $\pm 5^{\circ}F$ ($2.8^{\circ}C$).

During all life testing, each chamber operating at an elevated temperature was equipped with individual Blue-M Over-Temperature Trips, Model OTP-104, which were set $10^{\circ}C$ higher than the maximum temperature specified in each matrix group. No temperature deviations beyond the specified tolerances were experienced, however.

LIFE TEST SCHEMATIC

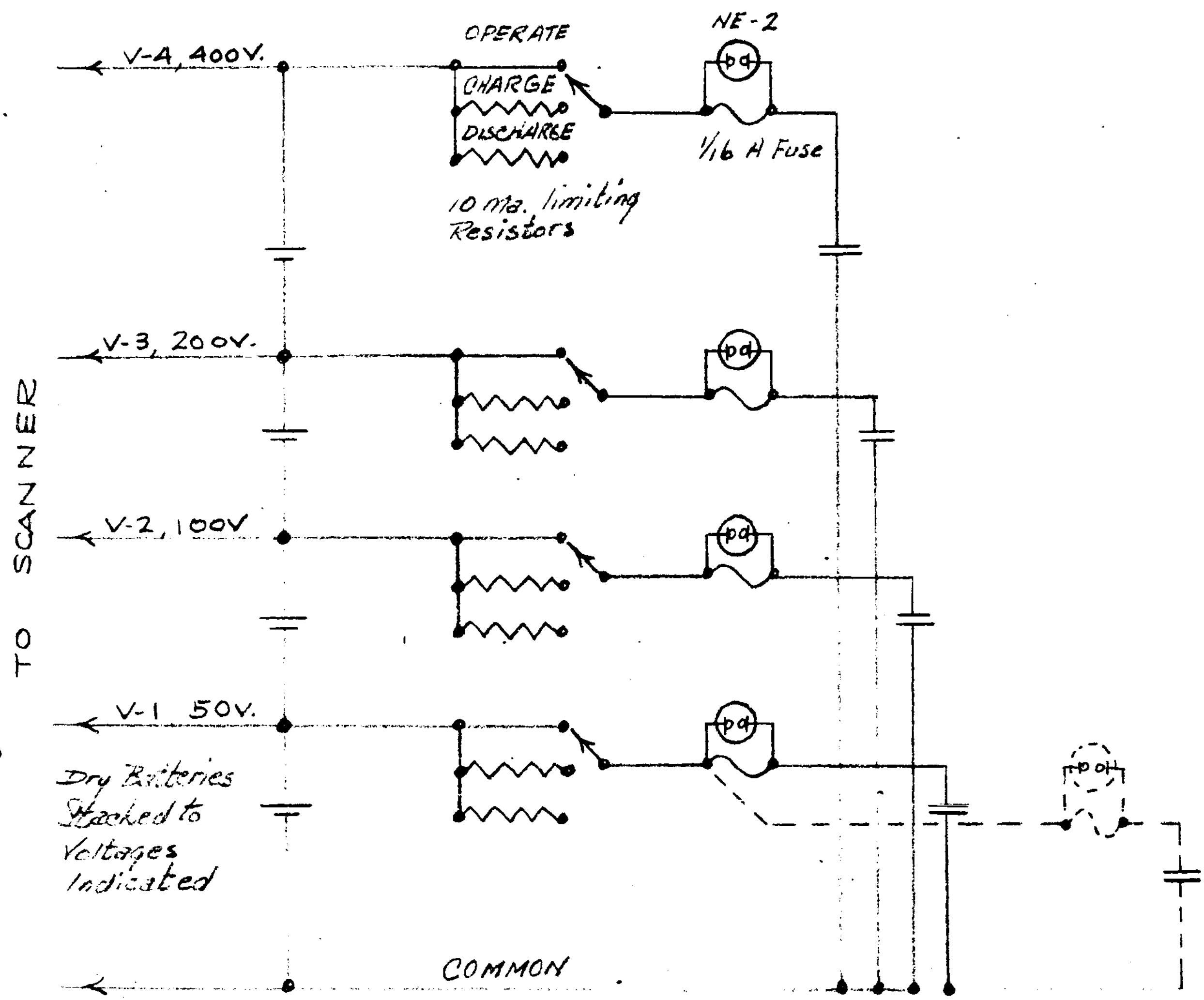

Figure 5-A

In order to provide voltage sources during the life test compatible with the requirements of JPL Test Procedure No. 152.20-03, dry batteries stacked to supply the required voltages were employed. Thus, the voltage source was capable of supplying 4 amperes through a shorted capacitor for 3 seconds or longer; transients and ripple content were eliminated. (The Test Procedure limited transients to 5% of the operating voltage and ripple content to not more than 0.1%).

As required, a charging current (2-3 ma) was applied across the batteries, using a regulated 400 VDC power supply, in order to maintain exact voltages throughout the life test period.

Each capacitor was connected in series with a 1/16 amp Slo-Blo fuse. Each fuse was bridged with an NE-2 lamp to visually indicate a shorted capacitor in order to properly log the time of failures. All shorted capacitors were tested with a second fuse so that all logged failures (shorts) during the life test are cases where two consecutive fuses were blown.

Voltage and Temperature Monitoring

Voltages and temperatures for all matrix cells were monitored during the entire life test period. This was accomplished by means of an automatic 12-channel stepping sequencer designed by PTS for this purpose. Monitoring data was recorded every 90 seconds in the following sequence:

Scanner Readout Sequence

Position	
1	Calibrate - 0 VDC
2	Calibrate - 0 VDC
3	T-1 (25°C)
4	T-2 (70°C)
5	T-3 (125°C)
6	T-4 (145°C)
7	Calibrate - 0 VDC
8	V-1 (50 VDC)
9	V-2 (100VDC)
10	V-3 (200 VDC)
11	V-4 (400 VDC)
12	Calibrate full scale

LIFE TEST VOLTAGE AND TEMPERATURE AUTOMATIC MONITORING SYSTEM

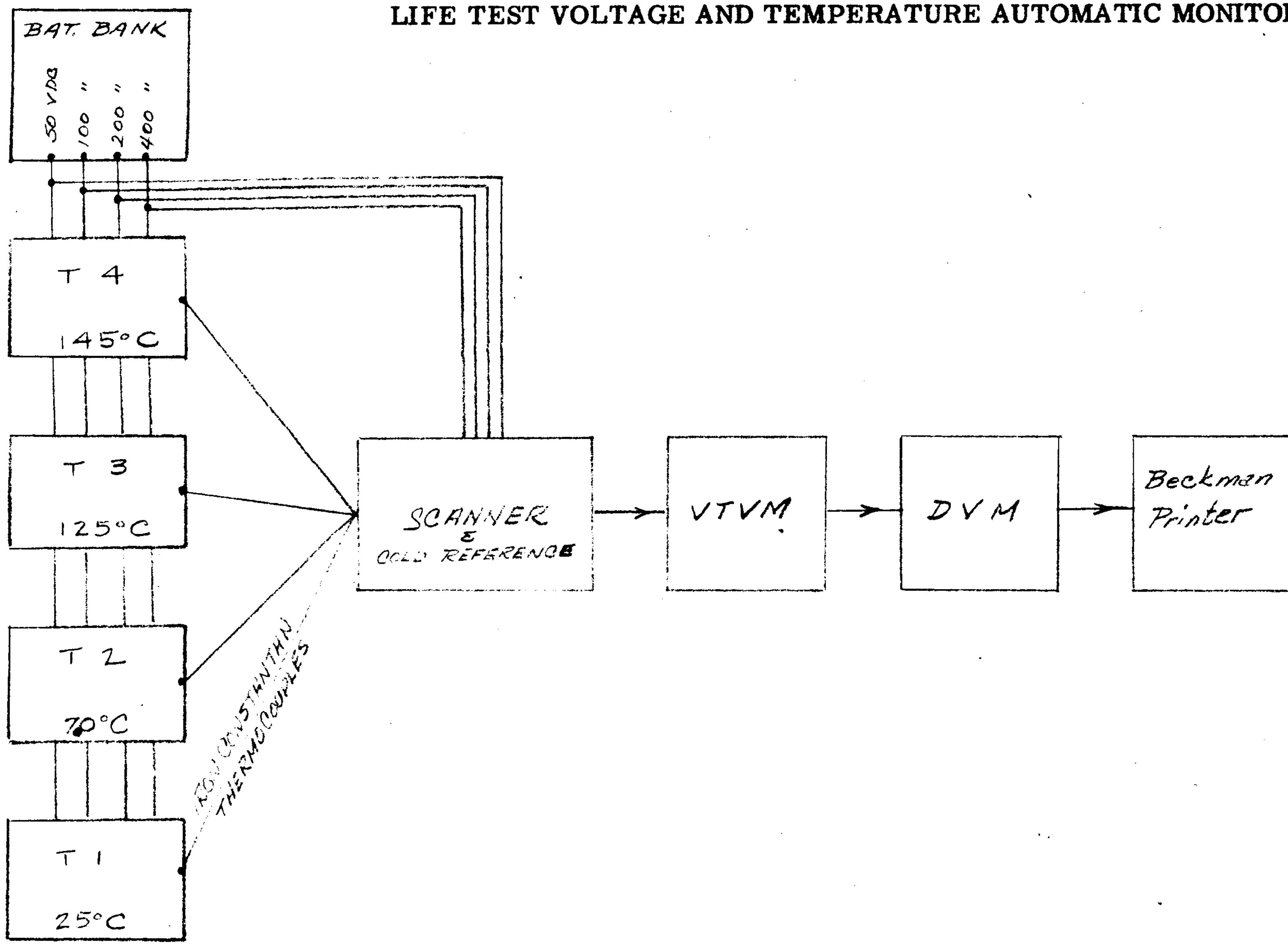

Figure 5-B

As can be seen from the above, each temperature and each voltage was recorded once during every 20 minute cycle.

A block diagram illustrating this system in shown in Figure 5B.

All voltages were recorded directly. Temperatures are recorded in millivolts, representing the output of the iron-constantin thermocouples positioned in each chamber. Millivolts corresponding to the various temperatures are shown below:

Temperature	Millivolts
25°C	1.28
70°C	3.65
125°C	6.63
145°C	7.73

On two occasions during the life test, system calibration checks indicated a deterioration of the mercury cell supplying voltage to the cold junction compensator. This resulted in brief intervals during which temperatures were recorded erroneously but in no way affected the actual temperatures which were maintained within the prescribed limits throughout the test. Temperature calibrations were performed with the Honeywell Brown Recorder at frequent intervals.

The tape on which all print-outs are recorded has been delivered separately to JPL.

Matrix Design

Test voltages, temperatures and quantity of specimens for each cell are shown in Figure 3A and in the tabulation appearing on page 3-5 of this report.

Handling

All handling of components after completion of initial inspection was in connection with taking measurements. Special precautions taken to avoid degradation by handling of the specimens are discussed on page 4-4 of this report.

Mounting

During all environmental exposures, the capacitors under test were mounted in standard PTS small component fixtures fabricated for this program. Four-contact-point beryllium-copper single coils were employed as lead connectors, assuring positive contact at all times. All fixtures were tested for leakage at room temperature before tests were started. All measured 2 x 10^{10} ohms or higher.

VI. DATA RECORDING

Except for the initial measurements, data was recorded on IBM mark-sense cards and punched in the standard PTS format. The exception, at the time initial measurements were taken, was made in order to facilitate a concurrent review and data check as the measurements were recorded. The data sheets were later key punched and verified.

All data were related to test specimens by tag numbers which were utilized by PTS for control during all tests. A master deck was prepared cross-referencing all tag numbers to JPL Item and Group numbers which served to identify each matrix cell and its individual components. At the completion of each measurement, all cards were matched to the master list to insure completeness. The applicable cross-reference information and other identification was then reproduced to the measurement card from the master deck.

PTS cards were employed for internal control of all data accumulation. Since the field format of these cards differs from the standard JPL format, new cards for delivery to JPL were reproduced from these in the JPL design, in accordance with JPL Spec. ZPP-2090-GEN-A dated 1 February 1965, as modified by Technical Direction Memorandum No. 4 dated 9 June 1965.

Information contained in the JPL cards by fields, and coding methods, are reproduced on the following pages.

CARD FIELDS

Col. No.	Data
1-2	Test Code
3-5	Component Code
6	Type of Test
7-8	Group Code
9-10	Temperature Code
11-12	Measurement Number
13	No. of parameters
14	No. of last field
15	No. of cards
16	No. of this card
17	Data form code
18-20	Item No.
21-24	Capacitance Measurement
25	Capacitance Range Code
26-29	Dissipation Factor Measurement
30	Dissipation Factor Range Code
31	X for negative I_L Reading
32-34	I_L Measurement
35	I_L Range Code
71	Failure Code

CODES

Measurement Code	Measurement
01	Initial
02	Post Burn-in
03	0 hour readout
04	24 hour life test
05	72 hour life test
06	168 hour life test
07	336 hour life test
08	672 hour life test
09	1344 hour life test
10	2688 hour life test

Temperature Code	Temperature
1	$25^{o}C$
2	$70^{o}C$
3	$125^{o}C$
4	$145^{o}C$

Group Code

See page 3-5

Range Codes

Capacitance (Col 25)

Negative exponent of 10 to yield microfarads, assuming whole number field.

Dissipation Factor (Col 30)

Negative exponent of 10 to yield dissipation factor, assuming whole number field.

Leakage Current (Col 35)

Negative exponent of 10 to yield amperes, assuming two decimal places in the field.

VII. TEST RESULTS

No drift tolerances were established for this program; therefore, all tabulated failures are of the catastrophic variety, either open or shorted electrically, or mechanically unfit to function.

An analysis of failures which occurred during the program is presented in Table A7.

Pre-Life Test Failures

Ten capacitors were rejected before environmental testing was started. Three of these had broken leads which were discovered during the initial inspection. Of the remaining seven, five were found to be open and two were shorted at the time the initial measurements were taken.

Two additonal capacitors were discovered to be open during the post burn-in measurements. Since each capacitor had already been assigned to a matrix cell when initial measurements were made before the burn-in operation, it was necessary to replace the nine electrical failures prior to life testing. These were replaced from the spares group as follows:

Failed Component Tag No.	Item No.	Group No.	Replaced by Tag No.
C104113	83	12	B16047
C104651	31	18	B15401
C104713	93	18	B16031
C104675	55	18	B16043
C104608	88	17	B16045
C104540	20	17	B15402
C104786	66	19	B16044
C104622	2	18	B15404
C104702	82	18	B16048

Life Test Failures

A total 25 test capacitors failed during the 2,688-hour life test. Three of these failures were mechanical (broken leads).

RECORD OF FAILURES

Initial Inspection and Measurement

Tag No.	Date	Remarks
B15479	4-12-65	Lead found broken in initial inspection
B16063	4-12-65	" " "
B16080	4-12-65	" " "
C104113	4-15-65	Shorted
C104651	4-16-65	Open
C104713	4-19-65	Open
C104675	4-19-65	Open
C104608	4-19-65	Open
C104540	4-19-65	Open
C104786	4-20-65	Short

Post Burn-in Measurement

C104622	5-21-65	Open
C104702	5-21-65	Open

Life Test

Item No.	Group	Date	Remarks	Hours to Failure
56	5	7-26-65	Short	324
96	7	7-8-65	Short	72
94	13	6-29-65	Lead broken	72
54	14	6-29-65	Lead broken	72
55	15	6-11-65	Short	12
36	15	6-11-65	Short	12
56	15	10-3-65	Short	1,836
57	15	10-17-65	Short	2,172
40	17	8-3-65	Lead broken	336
27	19	7-14-65	Short	168
90	19	9-27-65	Short	1,692
75	19	10-2-65	Short	1,812
58	19	10-7-65	Short	1,932
75	20	7-23-65	Short	276
72	20	8-4-65	Short	516
41	20	8-6-65	Short	564
52	20	8-13-65	Short	732
70	20	8-30-65	Short	1,140
66	20	9-7-65	Short	1,320
89	20	9-22-65	Short	1,572
86	20	9-17-65	Short	1,452
78	20	9-29-65	Short	1,840
57	20	9-21-65	Short	1,548
30	20	10-13-65	Short	2,076
1	20	9-23-65	Short	1,596

Table A7

The remaining 22 were eleotrial (shorts) which occurred during environmental stress exposure.

More than half (12) of the electrical failures occurred in the highest temperature - highest voltage matrix cell (Group 20). Cells 15 and 19 were next in order of failures with four each. These cells represent the highest voltage stress at next to the highest temperature (15) and the highest temperature stress at next to the highest voltage (19).

Thus, 20 out of 22 electrical failures (91%) occurred in the three highest stress cells. The remaining failures were distributed randomly. Of the entire 20-cell Matrix, 12 cells had no failures and three additional cells contained only mechanical failures.

Failures by cells are shown below:

Cell No.*	Temperature	Voltage	No. of Failures
5	25°C	400	1
7	70°C	50	1
13	125°C	100	1**
14	125°C	200	1**
15	125°C	400	4
17	145°C	50	1**
19	145°C	200	4
20	145°C	400	12
		Total	25

*Corresponds to Group No.

**Mechanical Failures

APPENDIX A

CROSS REFERENCE LISTING

From		To		From	To
Item No.	Group	Item No.	Group	Tag No.*	Tag No.*
001	1	050	1	3001	3050
051	1	090	1	3451	3490
001	2	100	2	3051	3150
001	3	100	3	3151	3250
001	4	100	4	3251	3350
001	5	100	5	3351	3450
001	6	050	6	3491	3540
051	6	090	6	3941	3980
001	7	100	7	3541	3640
001	8	100	8	3641	3740
001	9	100	9	3741	3840
001	10	100	10	3841	3940
001	11	050	11	3981	4030
051	11	090	11	4431	4470
001	12	100	12	4031	4130
001	13	100	13	4131	4230
001	14	100	14	4231	4330
001	15	100	15	4331	4430
001	16	050	16	4471	4520
051	16	090	16	4921	4960
001	17	100	17	4521	4620
001	18	100	18	4621	4720
001	19	100	19	4721	4820
001	20	100	20	4821	4920

*All Tag Numbers preceeded by "C10". This tabulation reflects serialization in accordance with initial assignments. Before life testing nine failures were replaced by spares, creating exceptions in the sequence shown. These replacements are shown on the following page.

REPLACEMENTS PRIOR TO LIFE TEST

Item No.	Group No.	Tag No.
83	12	B16047
31	18	B15401
93	18	B16031
55	18	B16043
88	17	B16045
20	17	B15402
66	19	B16044
2	18	B15404
82	18	B16048